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BUILDING MATERIALS AND STRUCTURES

REPORT BMS73

Indentation Characteristics of Floor Coverings

by

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and

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NATIONAL BUREAU OF STANDARDS

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Foreword

This report supplements Building Materials and Structures Report BMS14. It contains information on the effect of exposure to accelerated aging and the effect of elevated temperature on the indentation characteristics of floor coverings. The results of indentation and recovery determinations on a considerable variety of floor coverings are summarized and presented in graphic form to show their relative comfort value and resistance to permanent indentation under a concentrated load.

Lyman J. Briggs, *Director*.

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ABSTRACT

The indentation characteristics of 64 floor coverings were determined. Tests were conducted on specimens conditioned in an atmosphere of 65-percent relative humidity and 72° F temperature, on specimens after exposure to accelerared aging, and on specimens at an elevated temperature of 90° F. The floor coverings tested included such general types as linoleum, cork, rubber, felt base, asphalt, wood, fiberboard, and monolithic compositions. Variations in composition and thickness were included in many of the types. The apparatus and the procedures are briefly described. Summaries of the results are presented to show the relative merits of the various floor coverings with respect to comfort value and permanent indentation.

I. INTRODUCTION

As part of an investigation of the important properties of floor coverings being conducted by the National Bureau of Standards, a study was made of their indentation characteristics. This report supplements Building Materials and Structures Report BMS14, Indentation and Recovery of Low-Cost Floor Coverings. The previous report gives the results of indentation and recovery determinations at various loads for floor coverings in a comparatively new condition when in an atmosphere of 65-percent relative humidity at 72° F. The present report contains information on the effect of exposure to accelerated aging and the effect of elevated temperature on the indentation characteristics of floor coverings. The results of practical tests to determine the extent to which floor coverings are permanently indented by prolonged exposure to a concentrated load, such as may be imparted by small metal glides on furniture, are also presented in this report.

II. TEST EQUIPMENT AND PROCEDURE

Since the equipment and procedure used in making the indentation and recovery determinations have been described in detail in report BMS14, they are only briefly presented here.

The indentation tester is shown at the right of figure 1. The tester consists essentially of an indenting load (*A*) which can be lowered onto a plunger (*C*) equipped with an indenting tool (*H*). The indenting tool used in these determinations is a flat-ended cylindrical steel rod of ¼-in. diameter. A dial micrometer (*G*) indicates the depth of indentation in a specimen (*J*). The specimens were 2 by 2 in.

The gage, used to measure the original thickness of a specimen (*J*) as well as the thickness during recovery, is shown at the left of figure 1. The gage is equipped with a dial micrometer (*K*), graduated in thousandths of an inch, and a flat-ended foot (*L*) of ⅛-in. diameter. The foot exerts a pressure of 20 lb/in.^{2} on a specimen.

For testing under normal conditions, specimens of the various floor coverings were conditioned in an atmosphere of 65-percent relative humidity at 72° F for at least 48 hours. The thickness of each specimen was measured at a marked location in the central portion. The specimen was then placed under the indenting tool and the load applied. Time was recorded from the instant the full load rested on the specimen. The dial micrometer was read at intervals for 30 minutes. The load was then removed, and the thickness of the indented portion measured at intervals up to 120 minutes. Indentation and recovery determina-

tions were made on each floor covering for indenting loads of 25 and 100 lb, equivalent to pressures of 509 and 2,038 lb/in.[2], respectively.

The effect of accelerated aging on the indentation characteristics of the floor coverings was determined by exposing specimens to the heat and light of a carbon arc of a weatherometer amperes direct current with an arc voltage of 140 volts. The arc and globe were suspended at the center of a vertical metal cylinder which slowly rotated. The specimens were mounted on the inside of the cylinder facing the arc. The distance of the face of the specimens from the arc was approximately 14¾ in. A ther-

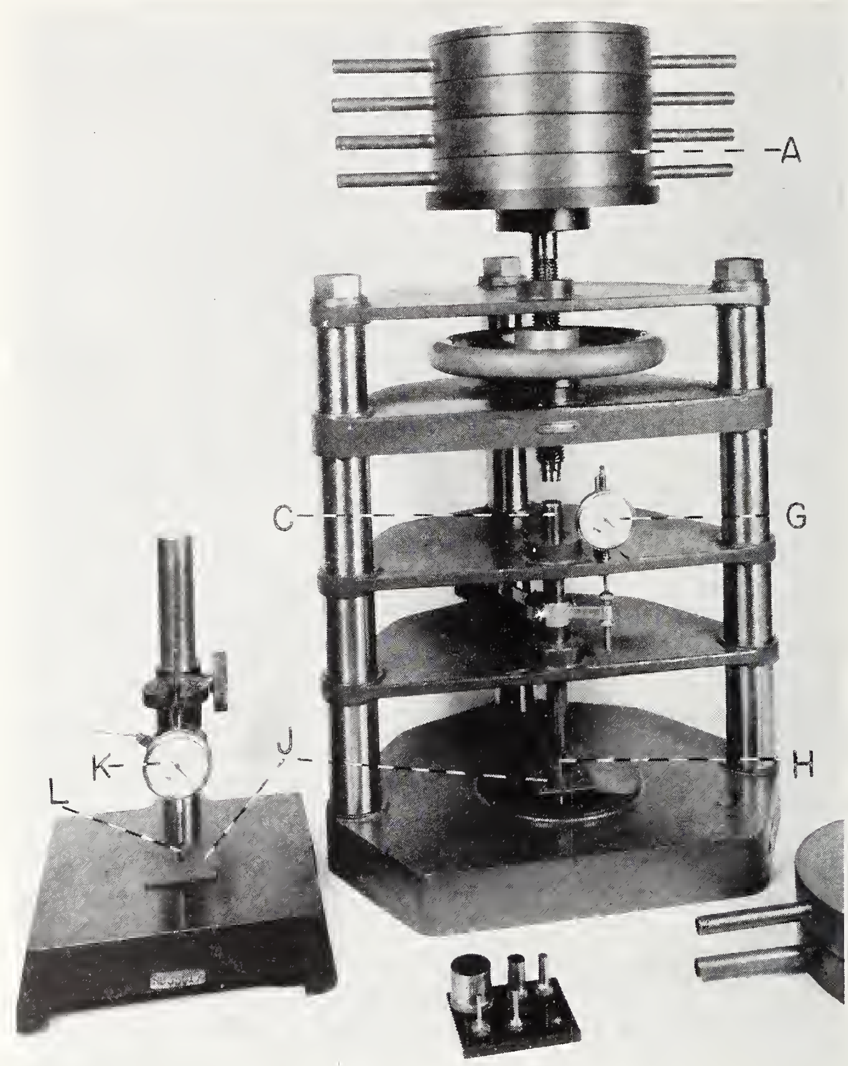

Figure 1.—*Indentation tester (at right) and thickness gage (at left).*

for a period of 28 days. The aged specimens were then conditioned and tested, following the same procedure as that used for testing specimens under normal conditions.

The weatherometer was equipped with a vertical carbon arc surrounded by a clear globe of Pyrex glass. The arc was operated on 13 mometer suspended directly in front of the specimens showed an average temperature of approximately 138° F.

To determine the effect of elevated temperature on the residual indentation characteristics of the floor coverings, specimens were conditioned in an atmosphere of 65-percent relative

humidity at 90° F for at least 48 hours. Indentation and recovery determinations were then made under the same atmospheric conditions for an indenting load of 100 lb.

Indentation tests of a practical nature were conducted on many of the floor coverings as an additional aid in determining their relative susceptibility to permanent indentation when exposed to concentrated loads for a prolonged time. The indenting apparatus consisted of three dome-shaped metal glides of ½-in. diameter mounted on one face of a 6- by 6-in. wood block. The three glides were equally spaced around the circumference of a circle of 4-in. diameter described about the center of the block. The procedure followed in testing was to place the wood block holding the three metal glides on the face of a specimen, the thickness of which had been previously measured at the locations where the glides contacted the specimen. The specimens were 6- by 6-in. squares, or in some cases three 2- by 2-in. squares. A load of 150 lb was then placed on the block for a period of 7 days. The thickness of the specimen at the indented locations was measured at 5 minutes and at 7 days after removal of the load. The average residual indentations in the various floor coverings at the above periods are recorded in table 1. The tests were conducted in an atmosphere of 65-percent relative humidity at 72° F.

III. DESCRIPTION OF SAMPLES

The floor coverings tested included such general types as linoleum, cork, rubber, felt base, asphalt, wood, fiberboard, alumina cement-latex, magnesium oxycholoride, and cement mortar. They are listed in table 1. Variations in composition and thickness were included in many of the types. The generous cooperation of manufacturers in furnishing materials is gratefully acknowledged.

TABLE 1.—*Floor coverings tested and the residual indentations caused by prolonged exposure (7 days) to a concentrated load (150 lb. on 3 metal glides of ½-in. diameter)*

Sample number	Floor covering: Type and description [a]	Floor covering: Nominal thickness	Average residual indentation: 5 minutes after removal of load	Average residual indentation: 7 days after removal of load
		Inch	*Inch*	*Inch*
1	Battleship linoleum; plain pattern, brown	¼	------	------
2	do	3/16		
3	do	⅛	0.018	0.009
4	Battleship lineoleum; plain pattern, gray	⅛	.023	.009
5	Battleship linoleum; plain pattern, green	⅛	.019	.010
6	Marbleized linoleum; marbleized pattern, green	⅛	.015	.007
7	Marbleized linoleum; marbleized pattern, tan	⅛	.013	.007
8	Marbleized linoleum; marbleized pattern, white	⅛	.011	.006
9	Jaspe linoleum; jaspe pattern, brown	3/32	.014	.006
10	Inlaid linoleum; molded pattern, gray	5/64	.011	.006
11	Printed linoleum; block pattern, brown; wearing surface, enamel	5/64	.014	.007
12	Linoleum tile; marbleized pattern, mahogany	⅛	.015	.006
13	Cork-composition tile; plain pattern, gray	⅛	.012	.003
14	Cork tile; light brown	5/16	.083	.041
15	Cork tile; dark brown	5/16	.095	.048
16	Rubber tile; marbleized pattern, black	¼	.007	.003
17	do	3/16	.007	.003
18	do	⅛	.006	.002
19	Rubber tile; marbleized pattern, white	3/16	------	------
20	Rubber tile; marbleized pattern, black	3/16	------	------
21	Rubber tile; marbleized pattern, gray	⅛	.006	.003
22	Sheet rubber, marbleized pattern, brown	⅛	.006	.003
23	Felt base; inlaid pattern, cream; wearing surface, linoleum composition	5/64	.015	.012
24	Felt base; jaspe pattern, brown; wearing surface, cellulose nitrate composition	5/64	.022	.018
25	Felt-base tile; jaspe pattern, brown; wearing surface, cellulose nitrate composition	5/64	.025	.022
26	Felt-base tile; jaspe pattern, green; wearing surface, cellulose nitrate composition	7/64	.033	.026
27	Felt base; mottled pattern, gray; wearing surface, resin-treated cotton-linters sheet	1/16	.017	.013
28	Felt base; mottled pattern, white; wearing surface, resin-treated cotton-linters sheet	5/64	.020	.014
29	Felt base; plain pattern, maroon; wearing surface, asphalt and pitch composition	3/32	.021	.019
30	Felt base; plain pattern, black; wearing surface, asphalt and pitch composition	5/64	------	------
31	Felt-base tile; plain pattern, red; wearing surface, asphalt and pitch composition	5/64	.023	.022
32	Felt base; printed pattern, lavender; wearing surface, enamel	1/16	.015	.011
33	Felt base; printed pattern, red; wearing surface, enamel	5/64	.021	.018
34	Asphalt tile; plain pattern, mahogany; 1-minute indentation, 0.010 in.[b]	3/16	.016	.012
35	Asphalt tile; plain pattern, mahogany; 1-minute indentation, 0.009 in.[b]	⅛	.011	.008
36	Asphalt tile; plain pattern, white; 1-minute indentation, 0.010 in.[b]	3/16	.024	.020
37	Asphalt tile; plain pattern, white 1-minute indentation, 0.008 in.[b]	⅛	.014	.011

See footnote at end of table.

TABLE 1.—*Floor coverings tested and the residual indentations caused by prolonged exposure (7 days) to a concentrated load (150 lb on 3 metal glides of ½-in. diameter)*—Continued

Sample number	Floor covering		Average residual indentation	
	Type and description	Nominal thickness	5 minutes after removal of load	7 days after removal of load
		Inch	*Inch*	*Inch*
38	Asphalt tile; plain pattern, green; 1-minute indentation, 0.012 in.[b]	3/16	.070	.068
39	Asphalt tile; plain pattern, green; 1-minute indentation, 0.010 in.[b]	1/8	.053	.053
40	Asphalt tile; plain pattern, red; 1-minute indentation, 0.010 in.[b]	3/16	.024	.021
41	Asphalt tile; plain pattern, red; 1-minute indentation, 0.007 in.[b]	3/16	.019	.015
42	Asphalt tile; plain pattern, black; 1-minute indentation, 0.010 in.[b]	1/8	.016	.014
43	Asphalt tile; marbleized pattern, white; 1-minute indentation, 0.006 in.[b]	1/8	.010	009
44	Asphalt tile; plain pattern, maroon; 1-minute indentation, 0.011 in.[b]	1/8	.015	.012
45	Strip Douglas fir; edge-grained; density, 27 lb/ft 3 [c]	25/32	.010	.007
46	Strip Douglas fir; edge-grained; density, 36 lb/ft 3 [c]	25/32	.006	.003
47	Strip yellow pine; flat-grained; density, 44 lb/ft 3 [c]	25/32	.008	.005
48	Strip white oak; flat-grained; density, 40 lb/ft 3 [c]	25/32	.005	.003
49	Short-strip maple; flat-grained; density, 47 lb/ft 3 [c]	25/32	.00[illegible]	.001
50	White-oak unit-block; flat-grained	1/2	.003	.002
51	Red-oak unit-block; flat-grained	1/2	.004	.003
52	Douglas-fir plywood; 5-ply	1/2	.011	.008
53	Rock-elm plywood tile; 3-ply	1/2	.005	.003
54	Rock-elm plywood tile; 3-ply	1/2	.008	.005
55	Rock-elm plywood tile; 3-ply	3/8	.006	.003
56	Pressed fiberboard tile; density, 67 lb/ft 3 [c]	1/8	.001	.000
57	Asphalt-impregnated fiberboard tile; dull black	1/4	.058	.044
58	Asphalt-impregnated fiberboard tile: green	1/4	.063	.045
59	Alumina cement-latex composition; aggregate, marble chips and volcanic ash; density, 120 lb/ft 3 [c]	1/4	.015	.012
60	Alumina cement-latex composition; aggregate, ground cork and silica; density, 61 lb/ft 3 [c]	1/4	.043	.017
61	Magnesium-oxychloride composition; aggregate, marble dust, cotton fiber, and copper powder; density, 108 lb/ft 3 [c]	1/4	-------	-------
62	Magnesium-oxychloride composition; aggregate, calcite; density, 108 lb/ft 3 [c]	1/2	.000	.000
63	Magnesium-oxychloride composition; aggregate, granite dust; density, 118 lb/ft 3 [c]	1/2	-------	-------
64	1:2 cement-mortar topping; aggregate, Potomac-River sand; density, 137 lb/ft 3 [c]	1	.000	.000

[a] Color listed is the predominating color.
[b] Method prescribed in Federal Specification SS-T-306, Tile; Asphalt.
[c] At 65-percent relative humidity and 72° F.

IV. SUMMARY OF RESULTS

The results of the indentation and recovery determinations on the 64 floor coverings are summarized and shown graphically in figures 2 to 13, inclusive. The values reported represent the average of separate determinations on at least three specimens. The quantity C is the initial indentation (30 seconds after application of the load) in mils for a load of 25 lb on the ¼-in. flat-ended indenting tool, and is used as an approximate measure of the relative comfort value of the floor coverings with respect to the physical fatigue of occupants. The quantity I is the residual indentation in mils 120 minutes after the removal of a load of 100 lb which has been applied for 30 minutes, and is used to show the relative extent to which the floor coverings are permanently indented by a severe load. The unshaded blocks show the indentation characteristics of floor coverings in a comparatively new condition when in an atmosphere of 65-percent relative humidity at 72° F. The single-shaded blocks show the results of similar tests on specimens exposed to accelerated aging. The double-shaded blocks show the residual indentations obtained on specimens at a temperature of 90° F.

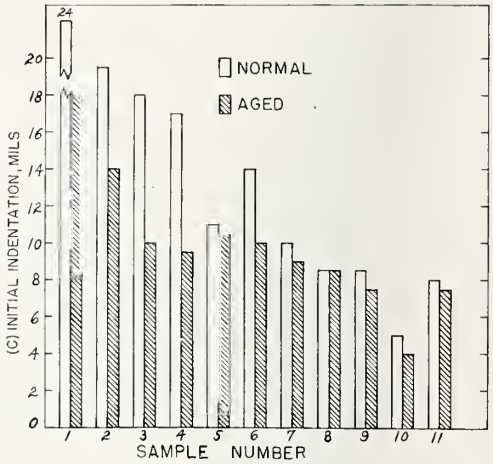

FIGURE 2.—*Sheet linoleums.*

C, initial indentation in mils for load of 25 lb. (An approximate measure of the relative comfort value)

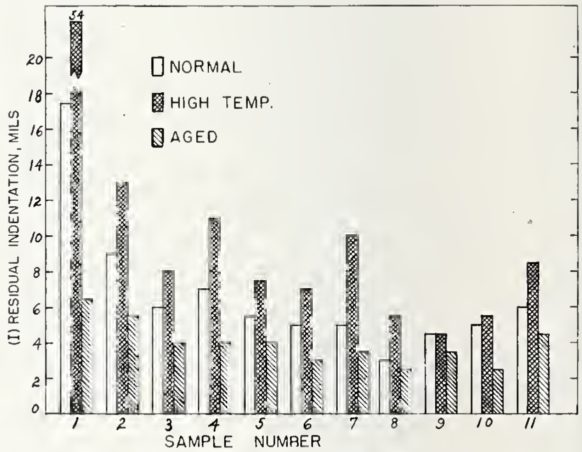

FIGURE 3.—*Sheet linoleums.*

I, residual indentation in mils 120 minutes after removal of load of 100 lb. (The extent to which the surface is permanently indented by a severe load)

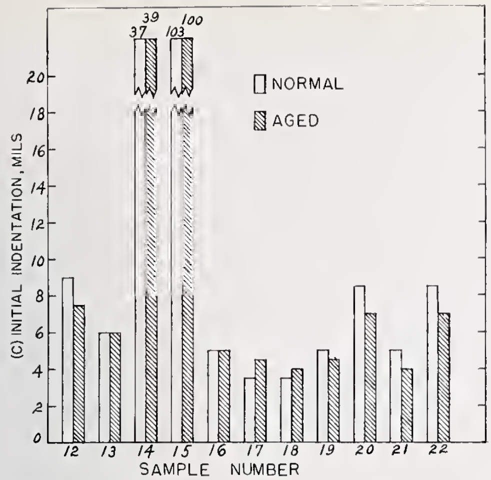

FIGURE 4.—*Linoleum tile, cork composition tile, cork tiles, rubber tiles, and sheet rubber.*

C, initial indention in mils for load of 25 lb. (An approximate measure of the relative comfort value)

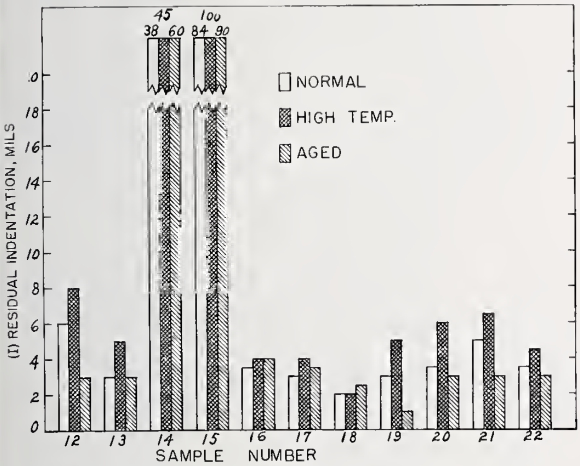

FIGURE 5.—*Linoleum tile, cork composition tile, cork tiles, rubber tiles, and sheet rubbers.*

I, residual indentation in mils 120 minutes after removal of load of 100 lb. (The extent to which the surface is permanently indented by a severe load)

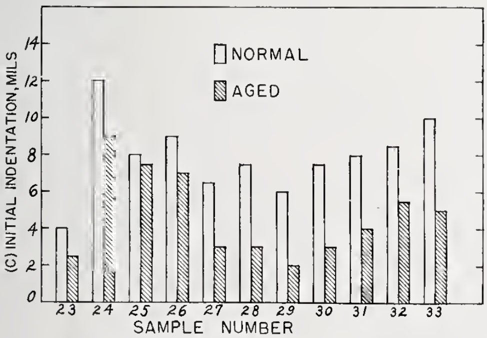

FIGURE 6.—*Felt-base floor coverings.*

C, initial indentation in mils for load of 25 lb. (An approximate measure of the relative comfort value)

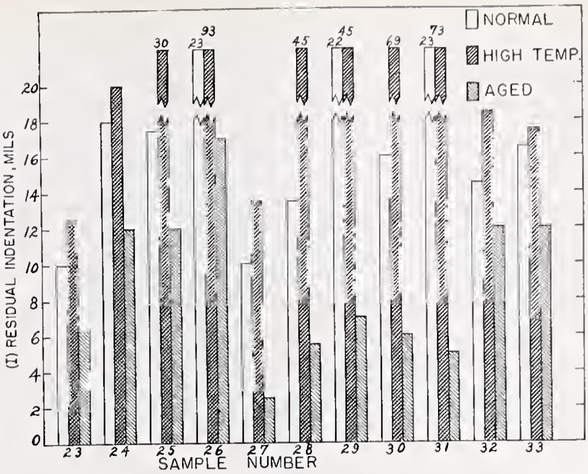

FIGURE 7.—*Felt-base floor coverings.*

I, residual indentation in mils 120 minutes after removal of load of 100 lb. (The extent to which the surface is permanently indented by a severe load)

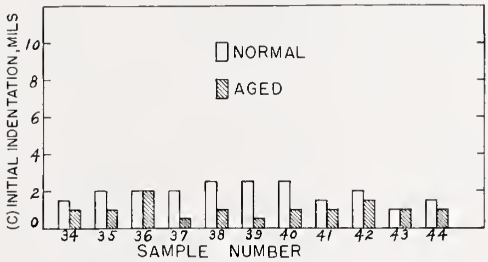

FIGURE 8.—*Asphalt tiles.*

C, initial indentation in mils for load of 25 lb. (An approximate measure of the relative comfort value)

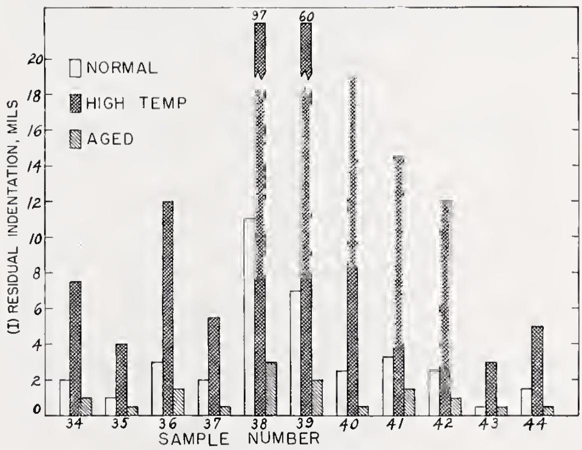

FIGURE 9.—*Asphalt tiles.*

I, residual indentation in mils 120 minutes after removal of load of 100 lb. (The extent to which the surface is permanently indented by a severe load)

In general, the effect of accelerated aging on the indentation characteristics of the floor coverings was a decrease in the depth of indentation under load as well as a decrease in the residual indentation after removal of a load. In view of the small decrease in the C value, even though an objectionable trend, in comparison to the decrease in the *I* value, which is a desirable trend, it would appear that accelerated-aging tests are not necessary for determining the indentation properties of floor coverings.

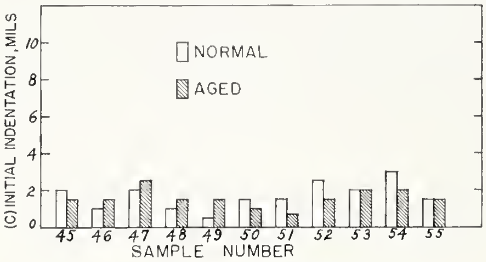

FIGURE 10.—*Woods.*

C, initial indentation in mils for load of 25 lb. (An approximate measure of the relative comfort value)

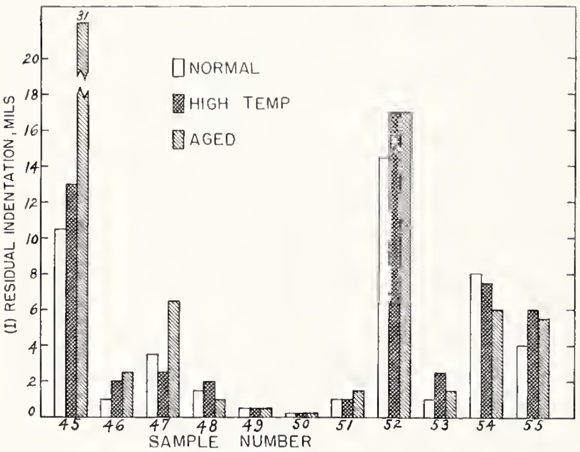

FIGURE 11.—*Woods.*

I, residual indentation in mils 120 minutes after removal of load of 100 lb. (The extent to which the surface is permanently indented by a severe load)

High temperature increases the residual indentation, or *I* value, in many of the floor coverings. In some the increase is small. In others it is appreciable and warrants consideration. Of the general types, those in which asphalt is used as an ingredient are the more noticeably and consistently affected.

The relative resistance of the floor coverings to permanent indentation as determined by tests of a practical nature and shown in table 1, is in good agreement with the relative resistance as shown by the *I* values under normal conditions presented in the figures, with the exception of the asphalt tiles, samples 34 to 44 inclusive,

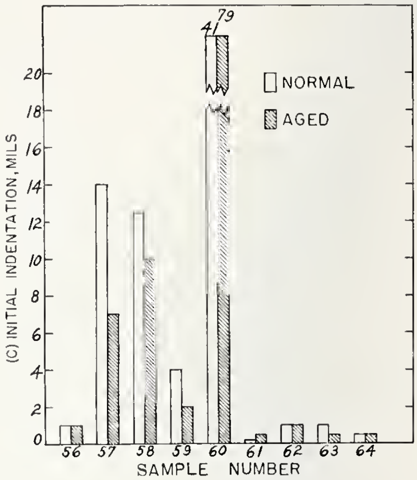

FIGURE 12.—*Fiberboards and monolithic compositions.*

C, initial indentation in mils for load of 25 lb. (An approximate measure of the relative comfort value)

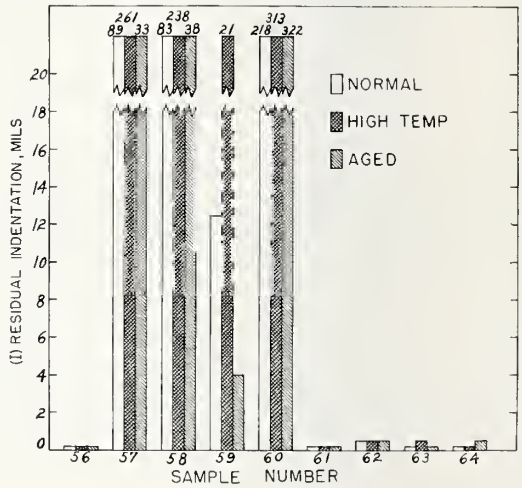

FIGURE 13.—*Fiberboards and monolithic compositions.*

I, residual indentation in mils 120 minutes after removal of load of 100 lb. (The extent to which the surface is permanently indented by a severe load)

and the alumina cement-like composition containing an aggregate of ground cork, sample 60. The relatively higher permanent indentations for asphalt tile, shown in table 1, are due to the characteristic of asphalt tiles in general to have a prolonged time-rate of indentation.[1]

[1] J. W. McBurney, Indentation of Asphalt Tile, Proc. Am. Soc. Testing Materials 34, pt. 2591 (1934).

The relatively higher I value for sample 60, shown in figure 13, is due to the crushing of the material at the higher pressure.

V. COMMENTS

The ideal floor covering for comfort and resistance to indentation is one which possesses a high C value and a low I value. Unfortunately, these two properties oppose each other in most floor coverings, and it is necessary to select a compromise between the two. Figure 14 represents a composite and convenient comparison of the indentation characteristics of the floor coverings under normal conditions.

C-VALUE (LOW ← → HIGH) \ I-VALUE (LOW ← → HIGH)	VERY GOOD	GOOD	FAIR	POOR	VERY POOR
VERY GOOD				1	14,15,60
GOOD		3,6	2,4		57,58
FAIR		5,7,8,9, 11,12,20,22	27	24,25,28,30, 32,33	26,31
POOR	18	10,13,16,17, 19,21,40	23,38,39,54	52,59	29
VERY POOR	34,35,37,43, 44,46,48,49, 50,51,53,56, 61,62,63,64	36,41,42,47, 55	45		

FIGURE 14.—*Composite comparison of the indentation characteristics of floor coverings under normal conditions.*

C-value, their ability to yield under foot.
I-value, their resistance to permament indentation under a concentrated load.

The numbers in the chart correspond to the sample numbers in table 1. It can be seen that most of the linoleums and the softer types of rubber floor coverings possess a fair to good combination of the C and I values. Exceptions in the linoleums were the $\frac{1}{4}$-in. battleship linoleum, sample 1, which had a high I value, and the $\frac{5}{64}$-in. inlaid linoleum, sample 10, which had a low C value.

If resistance to severe loads or abusive treatment is essential, a floor covering with a very low I value would be the least damaged or marred in such service. The oak and maple wood floors, pressed fiberboard, magnesium oxychloride floors, and the cement-mortar topping had a very low I value. Some of the asphalt tiles had a low I value under normal conditions. However, their I value was appreciably increased at an elevated temperature or by prolonged exposure to a concentrated load (see fig. 9 and table 1).

The cork tiles, samples 14 and 15, and the alumina cement-latex floor with an aggregate of ground cork, sample 60, were outstanding as regards a high comfort value. These floors, however, would require exceptional precautions against concentrated loads.

The indentation characteristics of the felt-base floor coverings, samples 23 to 33, inclusive, as a whole were not desirable. Although they had a fair comfort value, their residual indentations were high. It should not be concluded, however, that this group of floor coverings should not be considered. Their initial cost is comparatively low, and they may render economical and satisfactory service for some types of occupancy, provided they are amply protected from concentrated loads.

It should be noted that this report deals only with the indentation characteristics of floor coverings without consideration of other properties, such as resistance to abrasion, resistance to tear and fracture, dimensional changes with change in atmospheric conditions, and resistance to cleansing and finishing materials. Additional information on floor coverings is given in Building Materials and Structures Reports 14, 34, 43, 59, and 68 (see cover pages III and IV).

WASHINGTON, February 7, 1941.

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BMS9	Structural Properties of the Insulated Steel Construction Co.'s "Frameless-Steel" Constructions for Walls, Partitions, Floors, and Roofs	10¢
BMS10	Structural Properties of One of the "Keystone Beam Steel Floor" Constructions Sponsored by the H. H. Robertson Co	10¢
BMS11	Structural Properties of the Curren Fabrihome Corporation's "Fabrihome" Constructions for Walls and Partitions	10¢
BMS12	Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc	15¢
BMS13	Properties of Some Fiber Building Boards of Current Manufacture	10¢
BMS14	Indentation and Recovery of Low-Cost Floor Coverings	10¢
BMS15	Structural Properties of "Wheeling Long-Span Steel Floor" Construction Sponsored by Wheeling Corrugating Co	10¢
BMS16	Structural Properties of a "Tilecrete" Floor Construction Sponsored by Tilecrete Floors, Inc	10¢
BMS17	Sound Insulation of Wall and Floor Constructions	10¢
BMS18	Structural Properties of "Pre-Fab" Constructions for Walls, Partitions, and Floors Sponsored by the Harnischfeger Corporation	10¢
BMS19	Preparation and Revision of Building Codes	15¢
BMS20	Structural Properties of "Twachtman" Constructions for Walls and Floors Sponsored by Connecticut Pre-Cast Buildings Corporation	10¢
BMS21	Structural Properties of a Concrete-Block Cavity-Wall Construction Sponsored by the National Concrete Masonry Association	10¢
BMS22	Structural Properties of "Dun-Ti-Stone" Wall Construction Sponsored by the W. E. Dunn Manufacturing Co	10¢
BMS23	Structural Properties of a Brick Cavity-Wall Construction Sponsored by the Brick Manufacturers Association of New York, Inc	10¢
BMS24	Structural Properties of a Reinforced-Brick Wall Construction and a Brick-Tile Cavity-Wall Construction Sponsored by the Structural Clay Products Institute	10¢
BMS25	Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs	15¢
BMS26	Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc	10¢
BMS27	Structural Properties of "Bender Steel Home" Wall Construction Sponsored by The Bender Body Co	10¢
BMS28	Backflow Prevention in Over-Rim Water Supplies	10¢
BMS29	Survey of Roofing Materials in the Northeastern States	10¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association	10¢
BMS31	Structural Properties of "Insulite" Wall and "Insulite" Partition Constructions Sponsored by The Insulite Co	15¢
BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	10¢

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BUILDING MATERIALS AND STRUCTURES REPORTS

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